SafeMAP: Safe Multi-Agent Planning framework based on Dynamic Probabilistic Risk Assessment

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Abstract

This paper proposes a risk-aware framework for Safe Multi-Agent Planning (SafeMAP) that unifies disparate models for multi-agent systems in a Markovian process that allows for simultaneous system health monitoring, decision making under uncertainty, and multi-agent system collaboration. As operations beyond low earth orbit mature, there is an increased need for autonomous cyber-physical systems with onboard decision making capabilities. Multi-agent cyber-physical systems in particular offer the potential of increased efficiency, resiliency, and mission capabilities for future applications such as multi-rover terrain operations, distributed satellite operations, and management of smart lunar habitats. SafeMAP utilizes physics-based models of each agent and the relevant components, probability models of the environment and component operational states, and reward models for mission-specific objectives such as scientific task completion or resource consumption. The output of SafeMAP is a set of mission plans that satisfy the mission objective under specified risk/reward constraints. A readable interpretation of each of these generated mission plans is provided as an additional output. SafeMAP has been demonstrated on a simulated case study involving a four-rover system performing surface mapping operations and science tasks. Results of this paper demonstrate SafeMAP's ability to generate explainable mission plans that satisfy the mission objective while minimizing risk under nominal and off-nominal conditions.